APPENDIX C

ECOLOGY

C.1 INTRODUCTION

This appendix is based primarily on information from three documents: the Comprehensive Cooling Water Study (Du Pont, 1985, 1987), which presents data collected in 1982 and additional data collected through August 1985; a report that summarizes impingement and entrainment impacts at the SRP from 1983-1985 (DOE, 1987); and a report on studies conducted at the site to evaluate the potential effects of chlorination and dechlorination activities related to proposed cooling towers for K- and C-Reactors (Wilde, 1987). BB-1 BB-16 BD-5

In 1972, the Savannah River Plant became a National Environmental Research Park. The Plant has one of the most intensively studied environments in the country. More than 700 scientific publications have resulted principally from research efforts by three organizations at the Plant: the Savannah River Laboratory, the Savannah River Ecology Laboratory, and the U.S. Forest Service (Wiener and Smith, 1981). Other research efforts include (1) surveys of the aquatic ecology of the Savannah River since 1951 by the Academy of Natural Sciences of Philadelphia, (2) temperature and flow monitoring of the river since 1959 by the United States Geological Survey (USGS), (3) remote sensing of the Plant using aerial imagery, and (4) various ecological studies by the State of South Carolina and by industry. In addition, visiting scientists from other universities and laboratories in the United States have performed research. This appendix includes these studies as appropriate.

This appendix emphasizes Beaver Dam Creek, Four Mile Creek, Pen Branch, the Savannah River swamp, the Savannah River, and their important biota. These areas could be affected by the cooling water alternatives considered in this environmental impact statement. Important biota are those species that are (1) commercially or recreationally valuable, (2) endangered or threatened, (3) important to the well-being of the species included in categories 1 and 2, or (4) critical to the structure and function of the ecosystem.

C.2 SOILS

Soils are an important component of the environment because they influence the occurrence and distribution of the vegetation, wildlife, and potential land use. Figures C-1, C-2, and C-3 show the distribution of soils in the vicinity of C-Reactor, K-Reactor, and the D-Area coal-fired powerhouse, respectively; Table C-1 lists the characteristics of the soils shown in these figures. The C-Reactor soil map covers an area of approximately 1670 acres, while the K-Reactor map covers approximately 1770 acres. C- and K-Areas contain 19 soil types, of which udorthents and arents and urban are the most prevalent. These soils consist of material that has been previously deposited or material that remains after some of the soil has been removed; the material contains fragments or discontinuous layers of diagnostic horizons or layers. Streambed soils of Four Mile Creek and Indian Grave Branch consist primarily of Osier loamy sand; reactor operations have scoured and eroded these soils. The

Table C-1. Occurrence, Distribution, and Selected Characteristics of Soils Surrounding C-Reactor, K-Reactor, and D-Area[a]

Map symbol	Soil name	Texture (A horizon)	Drainage class
2	Ailey	Loamy sand	Well drained
5	Arents and udorthents	Sand or loam or sandy clay loam	Poorly drained
10	Osier	Loamy sand	Poorly drained
12	Blanton	Sand	Well drained
15	Tawcaw	Silty clay	Poorly drained
18	Dothan	Loamy sand	Well drained
22	Fuquay	Loamy sand	Well drained
23	Smithboro	Silt loam	Poorly drained
27	Lakeland	Sand	Well drained
29	Neeses	Loamy sand	Well drained
30	Norfolk	Loamy sand	Well drained
34	Ogeechee	Loamy fine sand	Poorly drained
35	Orangeburg	Loamy sand	Well drained
38	Rembert	Sandy loam	Poorly drained
40	Shellbluff	Loam	Poorly drained
42	Toccoa	Clay loam	Well drained
44	Troup	Sand	Well drained
45	Udorthents and arents	Loam	Poorly drained
46	Udorthents-Urban	Sandy clay loam	Well drained
47	Urban	Variable	Variable
50	Vaucluse	Loamy sand	Well drained
51	Vaucluse-Ailey complex	Loamy sand	Well drained
53	Wagram	Loamy sand	Well drained
55	Chastain	Loam	Poorly drained
56	Williman	Loamy fine sand	Poorly drained

a. Additional information for Figures C-1, C-2, and C-3: Capital letters that follow numerical map symbols designate slope classes: A = 0-2 percent, B = 2-6 percent, C = 6-12 percent, D = 12-18 percent, E = 18-25 percent.

dominant texture of the surficial horizons is loamy sand and sand; slopes typically range less than 12 percent, and most soils are well drained.

Figure C-3 shows the distribution of soils between the D-Area powerhouse and the Savannah River. The D-Area soil map covers an area of approximately 880 acres and consists of five major soil types. The udorthents-arents soil complex comprises more than 50 percent of the area. These soils consist of deposited material or material that remains after the surface layers have been removed or disturbed. The remaining soil types consist of Chastain clay loam, Smithboro loam, Tawcaw silty clay, Shellbluff loam, and Toccoa clay loam, all of which are frequently flooded and, except for the Toccoa series, are poorly drained. The Toccoa series is moderately well drained with good permeability.

C.3 VEGETATION - GENERAL SITEWIDE

The Savannah River Plant is located in an area where the oak-hickory-pine forest and the southern mixed forest intermingle (Kuchler, 1964). The southern floodplain forest (Kuchler, 1964), which adjoins major rivers such as the Savannah, is present. Dominant canopy species of the oak-hickory-pine forest include hickory, shortleaf and loblolly pine, white oak, and post oak. Beech, sweetgum, magnolia, slash and loblolly pine, white oak, and laurel oak characterize the canopy of the southern mixed forest. Typically, the southern floodplain forest consists of tupelo, many species of oak, and bald cypress. Species representative of each forest type exist on the Savannah River Plant. In addition, farming, fire, adaptive features, and topography have strongly influenced SRP vegetation. No virgin forest is in the region (Braun, 1950).

Since 1952, the U.S. Forest Service has managed the land surface at the Savannah River Plant for the Department of Energy and its predecessors. The Forest Service manages the land for multiple-use purposes, including environmental and ecological research areas, wildlife management areas for threatened or endangered species, and timber management areas (USDA, 1983).

Table C-2 summarizes the nine major land cover classes for SRP. The dominant land-use type is upland pine/hardwood (70.1 percent) followed by wetland (20.4 percent). The SRP wetlands are about 66 percent bottomland hardwood forests, primarily along streams and in the river swamp. A relatively small percentage (14 percent) of SRP wetlands are cypress and tupelo swamp forest, found predominantly in the Savannah River swamp. Normally, scrub-shrub and emergent marsh areas occur in thermal and post-thermal areas (Du Pont, 1985).

Table C-3 summarizes the wetland land-use types for the major SRP stream wetland communities.

C.3.1 FOUR MILE CREEK

Four Mile Creek, with Beaver Dam Creek, drains more than 22,480 acres. The Four Mile Creek floodplain has approximately 1900 acres of wetlands, primarily bottomland hardwood (72 percent) (Table C-3). Downstream from C-Reactor, open water and emergent marsh near the stream have replaced the original hardwood community. Away from the thermally affected areas in the floodplain, there is a hardwood canopy occupying 445 acres. Overall, C-Reactor discharges have affected about 1147 acres of Four Mile Creek wetlands. Discharges from F- and H-Areas and beaver activity have flooded original bottomland hardwood areas above the K-Reactor outfall, allowing scrub-shrub (260 acres) and emergent marsh (50 acres) wetlands to become established (Du Pont, 1985).

C.3.2 PEN BRANCH

Pen Branch and Indian Grave Branch drain about 13,590 acres above the swamp. Indian Grave Branch receives the effluent cooling water from K-Reactor. Pen Branch has about the same amount of wetlands (1725 acres) as Four Mile Creek (Table C-3). Similar to Four Mile Creek, emergent marsh (115 acres) and water (145 acres) are common below the K-Reactor discharge. Some hardwoods exist on the outer perimeter of the thermally affected areas (325 acres), but most

Table C-2. Land Use Types[a]

Land cover class	Area (acres)	Percentage
Upland pine/hardwood	135,100	70.1
Clear areas/power lines	11,200	5.8
Roads	4,100	2.1
Production areas	3,100	1.6
Subtotal	153,500	79.6
Wetland		
Bottomland hardwoods	25,900	13.4
Cypress-tupelo	5,500	2.9
Water[b]	4,400	2.3
Scrub-shrub	1,900	1.0
Emergent marsh	1,500	0.8
Subtotal	39,200	20.4
Total	192,700	100.0

a. Adapted from Du Pont, 1985.
b. Includes Savannah River.

occur in nonthermal tributaries (340 acres) or upstream of the K-Area cooling water releases (Du Pont, 1985).

C.3.3 BEAVER DAM CREEK

Beaver Dam Creek is a small stream that conveys thermal effluents from the D-Area coal-fired powerhouse. The creek is located 1 to 3 kilometers west of Four Mile Creek. A narrow band of bottomland hardwoods and scrub-shrub forest borders the stream from the D-Area process-water outfall to the Savannah River swamp (Du Pont, 1985).

C.3.4 SAVANNAH RIVER SWAMP

About 9400 acres (8 percent) of the Savannah River swamp forest lies on the Savannah River Plant from Upper Three Runs Creek to Steel Creek. The swamp is primarily cypress-tupelo forest (47 percent) and drier bottomland-hardwood islands (40 percent; Table C-4). On the islands, a few pine trees are able to survive (2.2 percent). The remainder of the swamp consists of scrub-shrub vegetation communities near the entry points of the thermal and post-thermal streams. Dense cypress-tupelo forest has been replaced by the mixture of scrub-shrub, and persistent and nonpersistent marsh vegetation in these delta areas. Delta areas comprise about 15 percent of the swamp, have more plant heterogeneity, and are changing (Du Pont, 1985).

Table C-3. Areas of Major SRP Stream Corridor Wetlands Communities (acres)[a]

Stream system	BH	SS	EM	CT	W	Total	Percent of total
Four Mile Creek							
Above C-Reactor (nonthermal)	925	255	50	0	0	1230	
Below C-Reactor (thermal)	445	0	65	0	150	660	
Total	1,370	255	115	0	150	1,890	8.3
Pen Branch							
Above K-Reactor (nonthermal)	725	60	0	0	0	785	
Below K-Reactor (thermal,	325	0	115	0	145	585	
nonthermal tributaries)	340	5	10	0	0	355	
Total	1,390	65	125	0	145	1,725	7.6
Other (Upper Three Runs, Lower Three Runs, Steel Creeks)	18,170	645	260	15	35	19,125	84.1
Total SRP	20,930	965	500	15	330	22,740	

a. Adapted from Du Pont, 1985.

Abbreviations:

BH - Bottomland hardwoods
SS - Scrub-shrub
EM - Emergent marsh
CT - Cypress-tupelo swamp forest
W - Open water

C.4 WILDLIFE

The Savannah River Plant was approximately two-thirds forested and one-third cropland and pasture when the U.S. government acquired it 35 years ago (Dukes, 1984). The abandoned fields were allowed to pass through vegetational succession or were planted in pine. The Plant is now 90 percent forested. The Plant is large, topographically variable, and diverse in vegetational history. It is in an area where major habitat types come together and intersperse. Human access is limited; therefore, faunal and floral diversity and abundance are high (DOE, 1984).

Because the proposed alternatives will primarily affect the fauna in the floodplains/wetlands, this section emphasizes species that depend on floodplain/wetland habitats for some part of their life cycle.

Table C-4. Area of Land Cover Classes Found in SRP Swamp (March 31, 1981)[a,b]

Class	Area (acres)	Percent of swamp
Persistent emergent marsh (PE)	135	1.4
Nonpersistent emergent marsh (NPE)	375	4.0
Scrub-shrub (SS)	385	4.1
Mixed deciduous swamp forest (MDSF)	4430	47.2
Mixed deciduous bottomland forest (MDBF)	3775	40.2
Needle-leaved evergreen forest (NEF)	205	2.2
Open water in swamp (W)[c]	65	0.7
Unclassified (U)	20	0.2
Total	9390	100.0

a. Obtained by analyzing multispectral scanner data (2440 meters AGL) provided by the Energy Measurements Group of EG&G, Las Vegas, Nevada.
b. Adapted from Du Pont, 1985.
c. Does not include 545 acres of Savannah River water adjacent to the swamp; probably includes some algal beds.

C.4.1 AMPHIBIANS AND REPTILES

Of the more than 90 species of reptiles and amphibians known to occur at the Plant, 61 use the SRP streams and wetlands. Most of these species inhabit post-thermal stream and swamp habitats in the vicinity of Steel Creek (Du Pont, 1985). The following list (adapted from Du Pont, 1985) contains the semi-aquatic species of reptiles and amphibians characteristic of SRP streams and swamps:

Amphibians

Salamanders - greater siren
two-toed amphiuma

Frogs - green treefrog
bird-voiced treefrog
bullfrog
bronze frog
pickerel frog
pig frog

Reptiles

Snakes - brown water snake
banded water snake
red-belly water snake
mud snake
rat snake
rainbow snake
cottonmouth

Turtles -	snapping turtle
	stinkpot
	striped mud turtle
	slider turtle
	river cooter
	Florida cooter
Alligators -	American alligator

Other species might occasionally occupy these habitats. A complete listing of species is in Du Pont, 1985.

No amphibians or reptiles persist on a routine basis in areas of severe thermal alteration. However, some species of frogs live in aquatic habitats that experience elevated temperatures and have deposited eggs in aquatic sites where lethal temperatures occurred (Du Pont, 1985).

Frogs and toads exhibit life history changes under elevated thermal conditions, particularly as tadpoles, by developing and metamorphosing more rapidly and at a smaller size than larvae living under normal temperature conditions (Du Pont, 1985).

The slider is the most prevalent species of turtle. This species apparently thrives in areas of moderately elevated water temperatures where it experiences faster growth rates and attains larger body sizes than turtles from local natural habitats. This can be attributed to improved diet quality, a longer growing season, and more rapid ingestion rates (Du Pont, 1985).

The striped mud turtle has been collected near the thermally elevated delta of Pen Branch. Original captures of this species were near Steel Creek before L-Reactor shutdown in 1968. No biological responses of this species to thermal conditions have been identified (Du Pont, 1985).

American alligators inhabit thermally affected streams such as Beaver Dam Creek and refuge areas along Four Mile Creek and Pen Branch (see Section C.6 details). A few other reptile species, primarily water snakes and turtles, might also occur in these areas, but not in numbers characteristic of ambient-temperature streams in the region (Du Pont, 1985).

C.4.2 AVIFAUNA

Several researchers have studied SRP avifauna. Norris (1963) surveyed the Plant in 1963. Fendley (1978) began a study in 1973 of the wood duck in the Steel Creek drainage system that has continued to the present. Angerman has conducted winter bird counts for several years (DOE, 1984). Dukes (1984) has summarized the avifauna studies.

Biologists have identified 213 species of birds at SRP. Angerman (1979; 1980) listed 59 species during recent Christmas bird counts. Game birds, particularly quail and dove, were abundant before the U.S. Government acquired the land. For a few years, the removal of land from agriculture did not decrease the quail population. In the early 1960s, this population reached a record high but began to decline because the conversion of agricultural fields to forests reduced the carrying capacity of the land.

Wild turkey, although present at Plant acquisition, were not very numerous. In 1972, the South Carolina Wildlife and Marine Resources Department started a program at the Plant for breeding wild turkey to stock other parts of the State. Thirty-six birds were released on the Plant between 1972 and 1974. Population growth was slow at first, but the turkey population has increased greatly in the last few years. To date, about 135 turkeys have been captured to restock other areas of the State.

Waterfowl are present primarily during winter migrations. After the construction of Par Pond, winter waterfowl species increased in number and diversity. An estimated 10,000 to 15,000 ducks and coots spend the winter at the Plant. Most of these birds are on Par Pond, other large ponds, and Carolina bays. Another 1000 to 2000 ducks spend the winter in the lower swamps and on the Savannah River. Wood ducks and hooded mergansers are the only waterfowl that commonly nest at the Plant.

In general, when clearing or cutting operations open wetland areas of the swamp or streams, a suitable habitat develops for ducks, wood storks, and other birds not normally found in mature cypress and tupelo stands. The increased flows and temperatures from reactor effluents to Four Mile Creek, Steel Creek, and Pen Branch have resulted in the development of such openings in the swamp. During the summer of 1972, bird surveys conducted on the deltas of Upper Three Runs Creek, Pen Branch, and Steel Creek in areas with similar densities of dead or living trees found no significant differences in non-aquatic bird communities in species diversity or richness in the natural (Upper Three Runs Creek), thermal (Pen Branch), and post-thermal (Steel Creek) swamps. However, more woodpeckers, crows, and herons occurred at Pen Branch than at Upper Three Runs Creek. The introduction of thermal effluents has produced a large stand of dead trees that serve as nesting and feeding sites for the large woodpecker and crow populations. Crows and herons represented more than 50 percent of the birds at Pen Branch Delta. Low numbers of these same species were seen near the open channel of Upper Three Runs Creek. When the canopy at Pen Branch was opened, suitable habitats became available to these larger species. The nonaquatic bird populations of the Four Mile Creek delta would be similar to those at Pen Branch.

A comparison of the number of mallards observed during 1982 aerial surveys in the Steel Creek delta area, Pen Branch delta, Four Mile Creek delta area, and Beaver Dam Creek revealed that this species used the delta areas of Four Mile, Steel, and Beaver Dam Creeks extensively. However, waterfowl were not observed in Pen Branch Delta. Mallard use of the Four Mile Creek delta area was generally higher than use of Steel Creek. Mallard use of the Four Mile Creek delta area was associated with open channels that branch off the main delta at a 90-degree angle. These channels are used heavily by waterfowl except when the water level is higher (flooding) or when the water is hotter.

The wood stork, an endangered species, forages on the site and is discussed in Section C.6.

C.4.3 MAMMALS

The Savannah River Plant has more than 40 species of mammals. The population of a few species increased rapidly and some species decreased after the Government closed the Plant to the public in 1952. The most notable expansion

was in the deer herd; the present population is estimated at about 3500. The population grew so rapidly that by the mid-1960s deer-vehicle collisions were common and range deterioration was apparent. Controlled public hunts were started in 1965 to reduce the deer population. From 1965 to 1983, hunters harvested an average of 1126 deer annually.

When the occupants relocated in 1952 for SRP, they abandoned some domestic hogs that multiplied and became detrimental to young forest plantations. Initially, a controlled program of shooting and trapping was used to reduce the hog population. Currently, deer hunters can shoot these feral hogs, and through 1983 had eliminated about 700. The present estimated population of feral hogs is between 500 and 1000. Except for deer, beaver, and feral hogs there is no authorized predation at SRP.

The following eight species of mammals are considered semiaquatic and are generally associated with the wetland/floodplain habitats:

Order Insectivora - Shrews and Moles

Family Talpidae
Condylura cristata - Star-nosed mole

Order Lagomorpha - Rabbits and Hares

Family Leporidae
Sylvilagus palustris - Marsh rabbit

Order Rodentia - Rodents

Family Castoridae
Castor canadensis - Beaver

Order Rodentia - Rodents (continued)

Family Cricetidae
Ondatra zibethicus - Muskrat
Oryzomys palustris - Rice rat

Order Carnivora - Carnivores

Family Procyonidae
Procyon lotor - Raccoon

Family Mustelidae
Lutra canadensis - River otter
Mustela vision - Mink

Order Marsupialis - Marsupials

Family Didelphiidae
Didelphis marsupialis - Opossum

None of these semiaquatic mammals inhabit reactor effluent streams during periods of elevated water temperatures. Beaver and otter, however, reoccupy these streams within 24 hours of reactor shutdown (Du Pont, 1985).

C.5 AQUATIC BIOTA

Six major aquatic habitat types occur at SRP: small ponds, Carolina bays, reservoirs, streams, and the Savannah River and its associated floodplain swamp. The surface areas of these waters vary in size, from less than 1 acre to about 2700 acres. Flows in the various streams range from intermittent to more than 11 cubic meters per second.

Water flow patterns through the swamp system bordering the Savannah River are complex; these patterns change depending on water levels in the Savannah River. Patterns are quite diverse; distinct water courses alternate with braided channels and broad flats of barely perceptible water movement. Many fish species use the swamp system as a spawning and rearing ground. Its use depends on high water levels, which increases spawning habitat. The swamp is one of the most variable habitats, exhibiting depth fluctuations of 4 meters or more along with the input of thermal effluents.

C.5.1 AQUATIC FLORA

Attached algae (periphyton) are the predominant primary producers in running-water environments like the Savannah River. Much of the phytoplankton (floating algae) community consists of true planktonic forms, as well as detached periphytic forms, that are discharged from upstream reservoirs and from backwaters and tributary streams.

Diatoms dominate the algal flora of the Savannah River. Although blue-green algae are at times an important component, particularly at upstream locations that are subject to organic enrichment from municipal effluents, industrial effluents, and agricultural runoff. The greatest algal diversity consistently occurs during the summer, coincident with low river flow and decreased turbidity, which allows greater light penetration.

Approximately 400 species of algae have been identified from the Savannah River near SRP (Patrick, Cairns, and Roback, 1967). Since 1951, when algal studies began, the diversity has decreased. Patrick, Cairns, and Roback (1967) suggested that this reflects an increase of organic loading to the river from the area above the Plant (ANSP, 1961, 1974).

Aquatic macrophytes in the river, most of which are rooted, are limited to shallow areas of reduced current in oxbows and along the shallow margins of tributaries. Eight species of vascular plants have been identified from the river adjacent to SRP; the most abundant are water milfoil, hornwort, alligator weed, waterweed, and duck potato.

Flora are greatly reduced in the SRP streams that receive thermal effluents, reflecting the influence of high flows and elevated water temperatures. The thermal gradient ranges from temperatures too high for most living organisms (70°C), through a thermophilic bacteria and algal zone, to near-ambient temperatures where the water enters the Savannah River. In addition, the

streams are sufficiently narrow to produce nearly horizontal and vertical thermal constancy; thus, the only refuges from the hot water are in tributaries or adjacent sloughs. Reactor effluent has increased the total flow to 10-20 times the normal stream flow. This flow has broadened and eroded the streambeds; eliminated rooted, aquatic vascular plants (macrophytes); reduced the overhead canopy, exposing the stream to sunlight; and accumulated silt deposits in some peripheral zones along the banks.

C.5.1.1 Beaver Dam Creek

Beaver Dam Creek immediately below the D-Area discharge structure is characterized by a deep (1 to 2.5 meters) channel and a substrate of shifting sand, fly ash, organic deposits, and occasional clay outcrops (Du Pont, 1985). Riparian vegetation is dominated by a narrow band of bottomland hardwoods and scrub-shrub forest, where wax myrtle, tag alder, willow, and buttonbush are dominant. Emergent macrophytes are present in off-channel areas, such as in oxbows, behind sand bars, and in swamp areas along the margins of the stream near the delta. These areas are dominated by cattail, cutgrass, and water primrose. Aquatic flora is dominated by thermophilic bacteria and blue-green algae (Du Pont, 1985).

C.5.1.2 Four Mile Creek

A relatively deep (0.3 to 1.5 meter), fast-flowing (about 140 centimeters per second) zone occurs where the main flow of Four Mile Creek courses toward the Savannah River (Du Pont, 1985). The flora is sparse, reflecting the influence of high flow and elevated (greater than 40°C) water temperatures. The substrate is primarily sand, organic matter, silt, and clay. In backwaters and shallow areas, particularly on clay outcrops, thick mats of blue-green algae cover the bottom. Riparian vegetation is dominated by tag alder and wax myrtle. Farther downstream toward the swamp, the stream is braided over a marsh-like area where a few standing dead bald cypress remain. In this area, defined and deeper channels are relatively free of vegetation. There are, however, thick growths of emergent macrophytes dominated by sedges, cutgrass, false nettle, and water purslane. In the shallower areas, thick mats of bluegreen algae cover the bottom.

C.5.1.3 Pen Branch

The upper reaches of Pen Branch are characterized by a substrate of sand and silt clay, while deep organic deposits occur in the many side channels (Du Pont, 1985). Blue-green algal mats similar to those in Four Mile Creek cover the substrate. Riparian vegetation includes sedges, grasses, wax myrtle, and buttonbush. Duckweed is abundant in the many side pools and channels.

The delta region of Pen Branch is characterized by an open and closed canopy of living and dead bald cypress and tupelo. Many channels braid through the area and the flow is generally in a shallow sheet. The dominant vegetation consists of smartweed, arrowhead, creeping burhead, water primrose, sedges, and duckweed. Fewer emergent plants are located at the closed canopy areas of the delta.

C.5.2 AQUATIC FAUNA

C.5.2.1 Macroinvertebrates

The structure and function of macroinvertebrate assemblages can indicate longterm conditions in a stream, due to their sensitivity to stress from pollution, and can be used in water quality evaluation (Weber, 1973). Thermal discharges have complex effects on macroinvertebrate communities (Hutchinson, 1976; Ward and Stanford, 1982). Increased water temperatures can accelerate or delay the emergence patterns of aquatic insects (Wise, 1980) and increase or decrease the number of generations (Parkin and Stahl, 1981; Rodgers, 1980). In some cases, elevated thermal regimes can significantly reduce species richness (Ferguson and Fox, 1978; Howell and Gentry, 1974). Other macroinvertebrate taxa can respond positively to increased water temperatures. For example, relative abundances of oligochaetes, nematodes, gastropods, and chironomid midges increase with thermal enrichment (Nichols, 1981; Rasmussen, 1982; Laybourn, 1979; Wood, 1982; Vincent, 1967; Ferguson and Fox, 1978).

To evaluate the response of macroinvertebrates to thermal stress and the longterm recovery of the macroinvertebrate community, samples were collected from nonthermal (Meyers Branch), thermal (Beaver Dam Creek, Four Mile Creek, and Pen Branch), and post-thermal (Steel Creek) streams, and from swamp locations on SRP between November 1983 and May 1984 (Du Pont, 1985). In addition, samples were collected at the mouths of Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek from September 1982 through August 1983 (Specht et al., 1984).

The number of macroinvertebrate taxa collected from each stream station varied considerably between thermal and nonthermal stations (Table C-5). The thermally perturbed sites had the fewest taxa. Many of the taxa recorded at these sites were not resident species, but were species that had invaded and colonized during reactor shutdown periods; most were eliminated when the reactor restarted.

In general, fewer macroinvertebrate taxa and lower densities of organisms were collected from thermal sites than from post-thermal or nonthermal sites (Table C-5). The macroinvertebrate communities of the thermal sites were dominated by oligochaetes (segmented worms), nematodes (round worms) and Diptera (primarily midges), while thermally sensitive taxa, such as mayflies, stoneflies, and caddisflies were absent or occurred in very low densities. Nonthermal and post-thermal sites exhibited more diverse assemblage of macroinvertebrate taxa. At thermal sites, collector-gatherers clearly dominated the macroinvertebrate functional groups, while at nonthermal sites there was a more even distribution of functional groups, indicative of a more balanced biological community.

C.5.2.2 Fish

The Savannah River and its associated swamp and tributaries exhibit a diverse fish fauna typical of other southeastern coastal plain rivers and streams. Many ecological studies during the past 30 years have included the adult fish of the Savannah River. Matthews (1982) reviewed those studies published by the Academy of Natural Sciences of Philadelphia between 1951 and 1976.

Table C-5. Composition of Stream Macroinvertebrate Community, Presented as Sum of Densities (no./m^2), December 1983 - May 1984[a]

	Stations[b]							
	Mildly thermal	Severely thermal			Nonthermal			
Taxa	1	2	3	4	7	8	11	12
Coelenterata	75	0	0	0	0	0	84	0
Turbellaria	0	0	0	0	10	17	117	8
Nematoda	12,747	4,965	6,707	2,763	3,750	1,205	10,284	5,221
Annelida								
Oligochaeta	19,718	412	6,178	45,612	15,185	18,001	8,812	7,923
Hirudinea	0	0	0	0	0	0	75	0
Crustacea								
Isopoda	0	0	0	0	8	0	83	0
Amphipoda	302	2	8	84	385	27	302	1,001
Decapoda	0	0	0	0	0	0	0	0
Hydracarina	557	8	6	75	640	210	2,354	590
Insecta								
Collembola	0	8	0	0	8	8	8	8
Odonata	153	0	0	0	0	302	0	75
Ephemeroptera	17	86	87	161	3,727	4,511	4,987	1,871
Plecoptera	0	0	0	0	385	2,172	2,455	2,955
Hemiptera	0	0	0	0	0	0	0	0
Megaloptera	0	0	0	0	49	6	2	17
Neuroptera	0	0	0	0	0	0	0	0
Trichoptera	127	151	11	120	5,347	2,489	2,981	4,368
Lepidoptera	0	0	0	0	0	0	8	0
Coleoptera	17	0	42	97	2,022	1,415	1,786	1,058
Diptera	5,860	3,023	19,575	13,287	100,199	66,233	76,290	84,085
Gastropoda	1,971	17	358	1,512	75	379	22	316
Pelecypoda	4,828	0	2	0	302	3,779	75	12,828

a. Source: Du Pont, 1985.
b. Stations 1 (Beaver Dam Creek), 2 and 3 (Four Mile Creek), 4 (Pen Branch), 7 and 8 (Steel Creek), 11 and 12 (Meyers Branch).

Bennett and McFarlane (1983) summarized the general distribution of fish within the major drainage systems of the Savannah River Plant. McFarlane, Frietsche, and Miracle (1978) and Dudley, Mullis, and Terrell (1977) reported the results of fisheries studies in the portion of the river near the Plant. In addition, the Georgia Game and Fish Division (1982) reported on an electrofishing survey conducted at 24 locations between the New Savannah River Bluff Lock and Dam and Port Wentworth. Rulifson, Huish, and Thoesen (1982) compiled data on anadromous species, many of which are important in the Savannah River. The most intensive study to date of the fish community of the SRP streams and the Savannah River (Du Pont, 1985) began in 1983.

This section summarizes the influence of thermal effluents on the fish community, specifically the distribution and abundance of adult and larval fish communities in nonthermal, post-thermal, and thermal streams; the effects of entrainment and impingement of adults and ichthyoplankton; the movement of fish into thermal streams; and the thermal tolerance of larval fish (Du Pont, 1985).

Fishes of Savannah River Plant Streams

Adult Fish of SRP Streams

Adult fish sampling began in September 1983 in nonthermal (Meyers Branch), thermal (Pen Branch and Four Mile Creek), and post-thermal (Steel Creek) streams (Figure C-4).

Nonthermal Streams - Relative abundance was greatest at the Meyers Branch station near Road 9 during the March 17 collection (Table C-6). The collection (401 fish) was dominated numerically by the yellowfin shiner (63 percent), bluehead chub (7 percent), pirate perch (5 percent), tessellated darter (5 percent), redbreast sunfish (4 percent), and spotted sunfish (3 percent). Steel Creek near Road B exhibited similar species composition and abundance during the March 10 collection; this collection (270 fish) was composed of 14 species and was dominated by yellowfin shiner (52 percent), bluehead chub (10 percent), northern hogsucker (9 percent), redbreast sunfish (9 percent), and flat bullhead (5 percent).

Post-Thermal Streams - The March 14, 1983, collection (Table C-6) from Steel Creek represented 23 species and 292 individuals. This sample exhibited the greatest species diversity, possibly due to its proximity to the Savannah River swamp. The collection was dominated by shiners (75 percent), darters (6 percent), and bullheads and madtoms (12 percent). This assemblage is a mixture of species usually associated with both stream channels and pools, backwaters, and vegetated areas along the channel.

Thermal Streams - Three locations were sampled on Pen Branch upstream of the K-Reactor outfall. A sample of site PB1, collected on April 2, 1984, was dominated by species associated with benthic-detritus microhabitats; it consisted of 76 individuals and 10 species (Table C-6). This sample was dominated by the mud sunfish (30 percent), brown bullhead (17 percent), dollar sunfish (16 percent), lake chubsucker (14 percent), and pirate perch (10 percent). Noticeably absent were species generally associated with fast-flowing water (i.e., darters).

Seventeen species of fish totaling 99 individuals were collected on March 29, 1984. Species composition was dominated by yellowfin shiner (42 percent) and sunfish (15 percent). Although there was a reduction in the total number of fish collected between September and March, the species composition remained nearly the same, indicating some degree of stability for the fauna.

One other location on Pen Branch exhibited relative abundance and species composition similar to those of the other streams surveyed. On March 26, 1984, 145 individuals representing 16 species were collected (Table C-6). The most abundant species were the yellowfin shiner (40 percent), sunfish (16.5 percent), and madtom (13.8 percent). TC

Movement of fish into the channels of thermal creeks (Pen Branch and Four Mile Creek) during reactor outages is directly related to the duration of a reactor outage. Thirty species of fish were collected in thermal creeks; 24 species were common to both Pen Branch and Four Mile Creek. Centrarchids were the fish collected most commonly, accounting for 47 percent and 45 percent of the fish collected from Pen Branch and Four Mile Creek, respectively. Other dominant taxa included the lake chubsucker (16-26 percent), the golden shiner (11-12 percent), and the longnose gar (1-14 percent).

However, samples collected from Four Mile Creek above the delta during a 50-day reactor shutdown in February 1984 were dominated exclusively by mosquitofish (Du Pont, 1985).

In general, fewer adult fish and a reduced species composition were noted from thermal streams than from post-thermal or nonthermal streams (Table C-6). The adult fish communities of the thermal streams above the outfalls were dominated by small fish (i.e., shiners and sunfish). However, during reactor shutdowns, the thermal streams below the outfall were dominated by mosquitofish. Post-thermal areas exhibited the greatest species diversity and reflected species composition typical of small headwater streams.

Ichthyoplankton of SRP Streams

Ichthyoplankton were sampled at 5 nonthermal, 16 post-thermal, and 14 thermal sites in SRP streams from mid-March through July 1984 (Paller et al., 1984). Nonthermal sites included three locations on Upper Three Runs Creek and two locations on Meyers Branch. Post-thermal sampling sites included three locations in Lower Three Runs Creek and 13 stations in Steel Creek. Three thermal streams, Beaver Dam Creek, Four Mile Creek, and Pen Branch, were sampled.

Nonthermal Streams - Ichthyoplankton abundance in the nonthermal stream-swamp area during 1984 was dominated by centrarchids (sunfish), catostomids (suckers), and percids (darters) (Table C-7). The spotted sucker was the most abundant species (55 percent) in the upper reaches of Upper Three Runs Creek, while crappie (21 percent) were the most prevalent species at the creek mouth. Ichthyoplankton densities were moderate to low (mean = 42 per 1000 cubic meters) at all stations. Meyers Branch was dominated by sunfish or bass (45 percent) and darters (30 percent). Densities were relatively low at the station near the mouth (18-67 per 1000 cubic meters), suggesting very little ichthyoplankton transport into Steel Creek from the upper reaches of Meyers Branch, which exhibited densities of 23 to 183 per 1000 cubic meters. The greater densities in the upper part of Meyers Branch might be related to more suitable spawning habitat. Several beaver dams in this area might provide good habitat for centrarchid spawning.

Post-Thermal Streams - During 1984, a total of 2785 ichthyoplankters were collected from Steel Creek and Lower Three Runs Creek (Table C-7). Relative abundance was much higher than that found in the nonthermal or thermal streams and was primarily the result of the locations of the sample collections. Generally, densities at swamp and creek mouth stations were substantially higher than at creek stations upstream from the swamp. The most dominant taxa during all collections were centrarchids (sunfish and bass, 28 percent),

minnows (25 percent), and darters (12 percent). Blueback herring (4 percent) were abundant in the creek mouths during April. The mean ichthyoplankton density was 175 per 1000 cubic meters during the March-to-June sampling period.

The predominant taxa collected from Lower Three Runs Creek were sunfish or bass (46 percent), crappie (20 percent), and darters (12 percent). The high densities collected in Lower Three Runs Creek were a result of samples collected immediately downstream of the Par Pond Dam (mean density = 1062 per 1000 cubic meters); they represent intense spawning activity in this tailwater area in combination with larval production in Par Pond that might have overflowed into the tailwater.

Thermal Streams - The D-Area effluent entering Beaver Dam Creek is considerably cooler than the reactor effluent (70°C) entering the other thermal creeks. Temperature data collected as part of the ichthyoplankton sampling program during 1984 indicated that the upper reaches of Beaver Dam Creek (Road A-12) averaged 20° to 25°C, while Four Mile Creek near Road A-13 averaged 30° to 45°C during the April-through-May sampling period. Temperatures decreased in Beaver Dam Creek from Road A-12 to the lowermost swamp station due to the gradual cooling of the water as it progressed downstream. However, temperatures increased at the mouth, probably due to an influx of heated water from Four Mile Creek through a channel connecting the lower reaches of Four Mile and Beaver Dam Creeks.

Ichthyoplankton densities in thermal streams ranged from total absence to very low abundance. Ichthyoplankton collected in the reactor streams between the outfalls and the swamp are believed to represent individuals that were transported into the streams from adjacent refugia, including nonthermal tributary streams, during periods of high river flow. These refugia appear to support self-sustaining (i.e., reproducing) populations of fish. In addition, ichthyoplankton abundance in thermal portions of the Savannah River swamp appears to be quite variable and strongly influenced by water levels in the Savannah River. It is also possible that the thermally impacted areas are utilized for spawning during high river flows, when flow patterns for the heated water are altered drastically.

A total of 463 ichthyoplankters was collected from the three thermal streams [Beaver Dam Creek (222), Four Mile Creek (203), and Pen Branch (38)] during the March-to-June 1984 sampling period (Table C-7). Sunfish or bass dominated the catch at both Beaver Dam Creek (38 percent) and Four Mile Creek (32 percent) while minnows (10 percent) and darters (10 percent) were dominant at Pen Branch. Beaver Dam Creek exhibited greater ichthyoplankton density and species diversity than the other thermal streams, but it did not produce the density of ichthyoplankton expected (considering the level of thermal loading observed was not much greater than in the more productive areas of the post-thermal Steel Creek delta).

C-Reactor did not operate during most of March 1984; therefore, mean temperatures in Four Mile Creek were only 5° to 10°C above Savannah River temperatures. Ichthyoplankton were not collected from the Road A station or the thermal delta during March, but were found in low densities in the swamp and creek mouth. Blueback herring were the most dominant in the delta while brook silversides were most dominant in the creek mouth.

C-Reactor was operating during April and May 1984; it produced temperatures in Four Mile Creek ranging from 33.9° to 50.1°C at Road A, and from 30.1° to 44.8°C at Road A-13. As expected, Four Mile Creek produced very little ichthyoplankton in its upper reaches (the area above Road A) with the exception of brook silverside and unidentifiable eggs; these eggs probably drifted into the channel of the creek from adjacent refuge areas. Temperatures in the heated swamp were lower and much more variable (18° to 42°C) due to the alteration of water flow patterns during river flooding. The extreme temperature variability in the heated swamp was due to the intermittent intrusion of relatively cool river water into the swamp during periods of high river level (Figure C-5). The river water displaced the thermal plume and created suitable habitat for fish in areas that had been thermally unsuitable. Most of the larvae collected from the swamp during April and May apparently were spawned during periods of high river level when the swamp was inundated with river water. Some larvae were collected when the temperatures were high during April; however, these might have drifted into the thermal swamp from adjacent cool-water refuge areas.

Few ichthyoplankton (38) were collected from Pen Branch during the March-to-June 1984 sampling period. Ichthyoplankton were either absent from the samples or present in low densities. The dominant species in the delta was the mosquitofish. This species is more tolerant of high temperatures than most, with an ultimate maximum temperature of 37.3°C (Hart, 1952). Most individuals were found in somewhat cooler refuge areas along the shoreline of the main thermal channel. Darters and minnows dominated the catch from above the reactor discharge area.

Researchers observed that, generally, ichthyoplankton densities at swamp and creek mouth stations were substantially higher than at creek stations upstream from the swamp. Sampling in the vicinity of the post-thermal Steel Creek delta revealed that spawning activity differs substantially in the different microhabitats available in that area. The deep-water, open-canopy areas were clearly the most productive for ichthyoplankton, with centrarchids (sunfish and bass), cyprinids (minnows), and percids (darters) dominating the collections. Although clupeids (herring and shad) were collected in the delta/swamp areas, the numbers were much lower than the numbers observed at creek mouth stations. Generally, it appears that anadromous species make minimal use of swamp areas for spawning and restrict spawning activities to creek mouth areas.

Ichthyoplankton densities in thermal streams were low. Ichthyoplankton collected in the reactor streams between the outfalls and the swamp are believed to represent individuals that were transported into the streams from adjacent refugia, including nonthermal tributary streams. These refugia appear to support self-sustaining (i.e., reproducing) populations of fish. Ichthyoplankton that are transported into the reactor effluent streams when reactors are operating are undoubtedly killed.

Ichthyoplankton abundances in thermal portions of the Savannah River swamp are quite variable and appear to be strongly influenced by water levels in the Savannah River. During periods of high river flow, ichthyoplankton appear to be transported into the thermally impacted portions of the swamp from adjacent unimpacted areas. It is also possible that the thermally impacted areas are

utilized for spawning during high river flows, because flow patterns for the heated water are drastically altered during such periods.

Ichthyoplankton densities in Beaver Dam Creek are lower than expected considering the low degree of thermal enrichment. Factors other than temperature probably are influencing fish spawning activities in this area of the swamp.

Adult Fish of the Savannah River Swamp System

The Savannah River Swamp System (SRSS) represents a very heterogeneous system of habitats supporting a diverse fish community of 60 to 65 species. Most species are resident; however, seven are either anadromous or catadromous. Anadromous (migrating from saltwater to freshwater to spawn) species include blueback herring, American shad, hickory shad, striped mullet, mountain mullet, and Atlantic needlefish. The only catadromous (migrating from freshwater to saltwater to spawn) species is the American eel. Several recreationally and commercially important species have been collected in the swamp; thus, the SRSS could be an important spawning habitat and nursery grounds for these species. This section summarizes the data collected on the adult fish community in the swamp system from October 1983 to April 1984 (Du Pont, 1985).

Adult fish were collected at three areas in the swamp: the Steel Creek delta; the Four Mile Creek delta, and a channel near Pen Branch (near Stave Island).

More than 1500 fish representing 40 species were collected from the swamp. The high species diversity was due to the wide array of habitat types available. The Steel Creek delta sample consisted of 32 species, of which brook silversides, various shiners, and largemouth bass dominated all catches.

Species diversity at stations in the delta-swamp area of Pen Branch were similar - 21 species dominated by brook silversides and various shiners.

Four Mile Creek stations differed among themselves and also from the other three delta-swamp stations. Fifteen species of fish were collected; gizzard shad and largemouth bass were the dominant species. Compared to the other stations, minnows were poorly represented at this station.

Researchers captured 149 migratory fish. The dominant species were longnose gar (48 percent), blueback herring (23 percent), channel catfish (10 percent), and various shad (12 percent). Researchers first observed blueback herring during the first week of March, while American shad did not appear until the last week of March. Conversations with local fishermen suggest that American shad were more numerous than blueback herring or hickory shad during 1984, and that a major run of blueback herring did not occur in Steel Creek.

Several trends are evident concerning the structure of fish communities within the SRSS. It appears that the increased species composition and the dominance by centrarchids and cyprinids are attributed to the diversity of microhabitats in the area. The swamp system is composed of extensive open water channels and macrophyte beds of various size. Centrarchids (bass and sunfish) and various suckers dominated the areas with extensive cover while minnows and brook silverside were most prevalent in the shallow open-water areas beneath the closed canopy. The swamp areas below the thermal streams were lower in habitat diversity and species composition.

Fishes of the Savannah River

The following introductory information was obtained from DOE (1987) which cites the primary source documents containing the data. TC

Streams of the southeastern Atlantic Coastal Plain generally contain a diverse fish fauna. One hundred six fish species have been reported from the Savannah River drainage basin; seventy-one species of anadromous and fresh water fish are known to occur in the river in the SRP vicinity. TC

The Savannah River supports both recreational and commercial fisheries. Bream and largemouth bass are the species most sought after by sport fishermen in freshwater sections of the river downstream of the New Savannah Bluff Lock and Dam. Channel catfish are taken by both sport and commercial fishermen. Anadromous species of importance in the Savannah River include American shad (Alosa sapidissima), hickory shad (Alosa mediocris), Atlantic sturgeon (Acipenser oxyrhynchus), shortnose sturgeon (Acipenser brevirostrum), and striped bass (Morone saxatilis). Both shortnose sturgeon and striped bass are protected from commercial harvest, and the shortnose sturgeon is listed as an endangered species. The catadromous American eel (Anguilla rostrata) is harvested commercially in some sections of the river.

Several identifiable factors potentially affect the productivity of Savannah River fish populations. Two areas of the lower Savannah River have been identified where water quality is substantially degraded because of wastewater input: below the New Savannah Bluff Lock and Dam from Butler Creek to downstream of Spirit Creek and in the Savannah Harbor area. Potential contributors to declining anadromous fish stocks include dams and impoundments, inadequate fishway facilities, reduction in spawning habitat, reduction in nursery areas, dredge and fill projects, poor food availability, and the location, type and magnitude of effluents into the Savannah River. BB-3

The species composition and relative abundance of Savannah River fish in the vicinity of the SRP were examined during 1982-1985 (ECS, 1983; Paller et al., 1984; Paller and Osteen, 1985; Paller and Saul, 1986). Collections were made along transects in the Savannah River and in the 1G and 3G intake canals using both electrofishing and hoop-netting techniques. Savannah River collections from four transects near the SRP intakes between RM 152.2 and 157.3 were analyzed for this evaluation. Collections were made quarterly from March 1982 to September 1985.

Scientific and common names of fish collected or known to occur in the Savannah River near SRP are presented in Table C-8. The dominant species collected in the Savannah River and the SRP intake canals during 1982-85 are presented in Table C-9. Other species comprising less than one percent of reported catches for either location or sampling gear are presented in Table C-10.

Adult Fishes of the Savannah River and Creek Mouths

This section summarizes the results of adult fish collections at 12 locations in the Savannah River, the intake canals, and the lower mouths of the five major SRP creeks. The data cover the sampling period from October 1982 to

Table C-10. Fish Species[a] Collected in Low Abundance[b] in the Savannah River or SRP Intake Canals, 1982-85[c]

Mud sunfish	Eastern silvery minnow
Redeye bass	Ohoopee shiner
White crappie	Notropis spp.
Striped bass	Unidentified minnow
White bass	Golden shiner
Hybrid bass	Hogchoker
Tesselated darter	Redfin pickerel
Logperch	Esox spp.
Blackbanded darter	Spotted gar
Lake chubsucker	Florida gar
Chubsucker	Snail bullhead
Highfin carpsucker	Speckled madtom
Silver redhorse	Eastern mudminnow
Quillback carpsucker	Mosquitofish

a. Scientific and common names of Savannah River fish species are presented in Table C-8.
b. Less than one percent of collections for any sampling method or location identified in Table C-9.
c. Source: DOE, 1987.

BB-3

August 1983, and are based on studies conducted by Environmental and Chemical Sciences, Inc., under contract to E. I. du Pont de Nemours and Company (Paller et al., 1984).

Researchers collected nearly 10,000 adult fish representing 66 species in the river, the intake canals, and the lower reaches of the major SRP creeks during the sampling period.

The electrofishing collections (Table C-11) indicated that sunfishes, especially redbreast, were the most abundant small species (except minnows), while bowfin and spotted sucker were among the most abundant large species during most or all of the year. Flat bullhead and channel catfish were important species, as indicated by hoop net collections, comprising 32 to 63 percent of the catch. Largemouth bass never comprised less than 7.9 percent of the electrofishing samples during any collection period. Other important species were American eel, white catfish, longnose gar, striped mullet, silver redhorse, chain pickerel, and quillback carpsucker.

Species composition varied due to seasonal changes in fish movement and activity (e.g., spawning). The most conspicuous change was a decrease in the relative abundance of sunfish during January (Table C-11). Bowfin, spotted sucker, flat bullhead, and channel catfish were more abundant during January. The greatest number of species was captured during May (37), possibly because of migratory movements or seasonal changes in activity related to spawning. Recruitment of young of the year might have increased the relative abundance of some species during August.

The sampling stations were located in four basic habitat types: the river proper, intake canals, the mouths of thermal creeks (Four Mile and Beaver Dam Creeks), and ambient creeks (Upper Three Runs, Lower Three Runs, and Steel Creeks).

In general, bluegill, black crappie, and chain pickerel were more abundant in the intake canals than in the other habitats, probably due to their preference for slow-moving water and weed beds. Redbreast sunfish were generally most abundant in the river and bowfin in the ambient creeks, especially Steel Creek. Four Mile Creek attracted numerous gar, bowfin, and gizzard shad during January, but was largely devoid of fishes during the other months. Channel catfish and various bullheads clearly dominated the hoopnet collections at all stations and seasons, probably due to gear selectivity. During the study period, the mean weekly water temperature of the thermal creeks was 14°C; it was 7°C in ambient creeks during the January sampling period. Largemouth bass and sunfishes dominated May catches at both thermal and ambient creek stations, although only 46 fish were collected in thermal creeks compared to 244 in ambient creeks. During May, the mean temperature was 31°C in the thermal creeks and 19.2°C in ambient creeks. Very few fish were collected from the thermal creeks during October or August (4 and 24, respectively). The mean temperature of the thermal creeks during the sampling periods was 27.7°C in October and 32°C in August; it was 15.0°C and 23°C, respectively, during the same months in ambient creeks.

Although the researchers did not sample small fishes and minnows quantitatively, they documented species occurrence and distribution. Species abundance was consistently less in the intake canals than in the river; mosquitofish, brook silversides, and lined topminnows were the most abundant in the canals. Small fish were absent from the mouths of Four Mile Creek and very scarce in Beaver Dam Creek during May and August. The low number of minnow species and small fish collected in these creeks paralleled the large fish collections and are probably the result of high temperatures during May and August (24.5°C to 41.2°C).

Researchers used the number of fish collected quantitatively with electrofishing to estimate the relative density (number of fish per 100 meters of shoreline) (Du Pont, 1985). The relative densities of fishes in the 1G and 3G intake canals (0.5 to 8.4 per 100 meters) were equivalent to the relative density in the river; however, the average weight of fish in the intake canals was approximately 40 percent lower than that in the river because of the predominance of bluegill and other small sunfishes. The seasonal relative abundances in the intake canals were comparable to those in the river.

Relative densities and seasonal trends in the mouths of the ambient temperature creeks were similar to those in the river, with low densities in January (0.3 to 0.5 per 100 meters) and higher densities in the other months (Table C-12). In contrast, the relative density in thermally influenced Four Mile Creek peaked during January (5.9 per 100 meters) at levels greater than those at the other transects (0.2 to 2.9 per 100 meters); this indicates a wintertime aggregation of fishes in the heated waters, which were as much as 7°C warmer than ambient river temperatures. Fish avoided Four Mile Creek during May, August, and October because of the excessively high water temperatures (29° - 41°C compared to 16° - 25°C in ambient creeks). Densities in Beaver Dam Creek during May and August (2.8 and 1.3 per 100

meters, respectively) were higher than in Four Mile Creek, but considerably lower than those in ambient creeks or river stations. Temperatures in Beaver Dam Creek were 5° to 7°C above ambient river temperatures, but were not as high as those in Four Mile Creek.

Researchers determined the approximate distances between the capture and recapture sites for 68 fish that were tagged in the river, canals, and creeks during the sampling program (Du Pont, 1985). Ninety-one percent were recaptured within 15 days at or near the point of tagging, indicating limited short-term movements. However, tag returns by fishermen indicated that some fish undertook extensive migrations (as far as 55 miles) upstream or downstream from the tagging location over a period of weeks or months.

Ichthyoplankton Abundance in the Savannah River

The abundance of ichthyoplankton is one measure of the reproductive success of fishes; concentrations of ichthyoplankton can indicate important spawning sites, identify impacted and control areas, and provide information for entrainment and impingement losses.

Recent studies on ichthyoplankton of the mid- and lower reaches of the Savannah River began in 1982 and ended in 1985 (ECS, 1983; Paller et al., 1984; Paller, O'Hara, and Osteen, 1985; Paller, Saul, and Osteen, 1986). The 1982 studies were restricted in scope, and included seven river transects between RM 141.5 and RM 157.3 and SRP intake canals 1G and 3G (Figure C-6, Table C-13). The 1983 and 1984 studies included 26 river transects between RM 29.3 and RM 187.1, and the two intake canals. The 1985 study was slightly truncated, and included 21 river transects between RM 89.3 and RM 187.1 and the two intake canals. Sampling in 1982 was conducted on alternate weeks from March through August, while in subsequent years, sampling was conducted weekly from February through July. This consideration of entrainment at the SRP will emphasize ichthyoplankton collections in the vicinity of the SRP intake canals during 1983-1985.

The ichthyoplankton assemblage in the Savannah River consists of a variety of species which differ in recreational, economic and ecological importance. Among the most abundant ichthyoplankton taxa in the Savannah River are gizzard and/or threadfin shad, American shad, blueback herring, sunfishes, crappie, minnows and suckers (Table C-14). Generally, the clupeids (including anadromous American shad and blueback herring, and resident gizzard and threadfin shad) dominated collections in the Savannah River during 1983-1985. The blueback herring, while somewhat less abundant, is another anadromous species used for commercial purposes in some coastal areas. Some species, such as the largemouth bass and other centrarchids, were comparatively abundant as adults in the Savannah River, but scarce in the ichthyoplankton collections because their eggs and larvae reside in sheltered areas where they are unlikely to become entrained in currents and carried into open water. Such species are less susceptible to SRP entrainment impacts than those that produce drifting eggs and larvae. BB-3

All clupeid taxa exhibited considerable variation in abundance among years. American shad eggs and larvae increased in relative abundance from 1.4 percent to 50.7 percent of collections between 1983 and 1985. Concurrently, blueback

Table C-14. Percent Composition of Fish Eggs and Larvae Collected in the Savannah River, 1983-85[a]

Taxa	1983[b]	1984[b,c]	1985[c,d]
American shad	1.4	14.0	50.7
Blueback herring	12.1	4.5	2.2
Gizzard and/or threadfin shad	19.9	10.8	9.9
Unid. clupeid	6.7	7.6	3.3
Striped bass	0.2	3.0	5.4
Spotted sucker	5.0	4.3	8.1
Unid. sucker	0.8	0.7	0.4
Pirate perch	8.0	0.3	0.1
Yellow perch	3.5	1.1	0.2
Darter	2.6	2.7	0.7
Sunfish (Lepomis)	2.1	6.9	0.7
Unid. sunfish	1.1	4.0	0.3
Crappie	16.6	13.5	0.3
Mudminnow	<0.1	<0.1	0.0
Swampfish	<0.1	<0.1	<0.1
Minnow (Cyprinid)	14.0	13.5	3.7
Carp	3.6	3.2	4.6
Mosquitofish	<0.1	<0.1	<0.1
Topminnow		<0.1	<0.1
Needlefish	<0.1	0.1	<0.1
Silverside	0.2	0.2	0.1
Catfish and/or bullhead	0.1	<0.1	0.1
Pickerel	0.3	0.1	<0.1
Sturgeon	<0.1	<0.1	0.1
Gar	<0.1	<0.1	0.0
Unidentified	1.7	9.8	9.2
Total numbers	36,941	18,267	22,698

a. Source: DOE, 1987.
b. Based on 26 transects between RM 29.6 and 187.1.
c. Does not include intake canals.
d. Based on 21 transects between RM 89.3 and 187.1.

herring decreased from 12.1 percent (1983) to 2.2 percent (1985) of collections. Gizzard and/or threadfin shad relative abundance paralleled the decline in blueback herring.

Some of the decline in the relative abundance of blueback herring from 1984 to 1985 could be attributable to the reduction of sampling effort in the lower reaches of the Savannah River, because this section of the river appears to be a major spawning area for the species (Table C-15a). However, the decrease in density from 1983 through 1985 was also observed in the mid-reaches of the

river (Tables C-15b and C-15c), and is more likely related to variations in spawning stock abundance or the availability of spawning sites. Low river water levels, especially during the 1985 spawning season, likely reduced access to swamp and backwater spawning sites used by blueback herring (Paller et al., 1986). The sharp increase in American shad ichthyoplankton abundance from 1983 to 1985 may be related to variations in spawning stock abundance.

Striped bass spawning in the upper reaches of the Savannah River had not been documented prior to 1982 (ECS, 1982). Dudley et al. (1977) reported that striped bass spawning was restricted to the lower reaches of the river and McFarlane et al. (1978) collected no striped bass ichthyoplankton during their sampling in 1977. However, striped bass eggs and/or larvae were collected during each year of the Comprehensive Cooling Water Study (Table C-14), and the highest densities occurred between approximately RM 166 to RM 120 during 1983-1985 (Tables C-15a, C-15b and C-15c). Although total striped bass ichthyoplankton abundance was substantially lower than found for American shad, striped bass showed a similar trend in abundance with a substantial increase from 1983 to 1985.

Ichthyoplankton relative abundance and densities for many of the abundant resident fish taxa (e.g., gizzard and/or threadfin shad, pirate perch, crappie and minnows) declined from 1983 to 1985 (Tables C-14, C-15a, C-15b, and C-15c). Suckers exhibited a slight increase and sunfish ichthyoplankton relative abundance was somewhat higher in 1984 than in either 1983 or 1985.

Sturgeon larvae were collected from the Savannah River in the vicinity of the SRP during 1982. Examination of these specimens indicated that both Atlantic sturgeon and the endangered shortnose sturgeon were present (Table C-16). Both sturgeon species have been collected in all subsequent years. Although total sturgeon larvae collections (number of specimens) were highest in 1982, sampling intensity was lowest (Table C-13). Generally, it appears that both species spawn upstream or near the SRP and that shortnose sturgeon spawn earlier and at cooler water temperature than Atlantic sturgeon.

Atlantic and shortnose sturgeon are demersal in nature. Consequently, most larvae were collected in samples near the river bottom. The National Marine Fisheries Service had previously concurred with DOE's determination that the population of shortnose sturgeon in the Savannah River would not be adversely affected by SRP operations (Oravetz, 1983).

Ichthyoplankton Abundance in the Mouths of Savannah River Tributaries - Twenty-seven creeks, ranging from small intermittent streams to major tributaries, were sampled for ichthyoplankton from February through July 1983. Five of these creeks - Beaver Dam Creek, Upper and Lower Three Runs Creeks, Four Mile Creek, and Steel Creek - drain portions of the Savannah River Plant. Researchers collected 5714 larvae and 1423 eggs from all the streams during 1983 (Table C-17).

TE Streams accounted for 8.8 and 14.4 percent of the fish eggs and larvae, respectively. Ninety-four percent of all eggs collected were from Spirit Creek (1230) and Steel Creek (103) (Table C-17). The high number of fish eggs collected at Spirit Creek were threadfin or gizzard shad, taken during May and June. Clupeids were the numerically dominant taxa in all streams; however, crappie, centrarchids, and yellow perch were also important.

The number of ichthyoplankters transported from creek to river ranged from approximately 0.1×10^6 from Lower Boggy Gut to 342×10^6 from Coleman Lake (Table C-17). Steel Creek and Beaver Dam Creek accounted for 77.2×10^6 and 7.5×10^6 ichthyoplankters, respectively, the greatest production of any of the SRP streams. Some creeks exhibited high densities but low transport numbers due to their low discharge rates.

Considerably more fish spawning occurred in Four Mile Creek in 1983 than in 1982, apparently due to unusually high river levels that reversed stream flow and lowered water temperatures enough to allow fish to enter the creek and from the transport of ichthyoplankton from nearby refuge areas into the creek when river levels receded. Centrarchids, blueback herring, and shad dominated the larval catch. Ichthyoplankton densities were low to moderate in March, peaked at 332 per 1000 cubic meters on April 4, and declined to zero by early June (Table C-17). Larvae collected during May were taken at temperatures between 35° and 37°C and represent larvae transported from refuge spawning areas in the Four Mile Creek watershed. Although more ichthyoplankton were collected in 1983, similar medium-sized streams had higher densities and longer spawning periods. The mean temperature in these creeks was often as much as 15°C lower than that in Four Mile Creek. Apparently, the elevated temperatures in this stream limited spawning. Transport of ichthyoplankton from Four Mile Creek was very low (2.7×10^6), ranking it as twenty-first of the 27 streams sampled (Table C-17).

During sampling trips, researchers collected 138 fish larvae and 10 fish eggs on Beaver Dam Creek (Table C-17). Sunfish, silversides, and yellow perch dominated species composition. Because of excessively high river levels, Beaver Dam Creek was not sampled during February, March, or most of April. Subsequent sampling indicated a peak density of 320 per 1000 cubic meters (primarily sunfish) in early May, which declined to low densities by July. Similar-sized streams had higher densities, mainly because of high shad concentrations. Temperatures in Beaver Dam Creek were generally 3° to 7°C higher than in similar-sized creeks. Although elevated temperatures might have reduced spawning later in the year in Beaver Dam Creek, the effect was not as pronounced as that in Four Mile Creek. The number of ichthyoplankters transported from Beaver Dam Creek (7.4×10^6) was equivalent to or greater than from other creeks that did not have large numbers of threadfin or gizzard shad. TE

Effects of Cooling Water Intakes

The once-through cooling water systems for C- and K-Reactors each withdraw about 11 cubic meters of water per second from the Savannah River through the 1G and 3G pumphouses. An additional 1 cubic meter per second enters these intakes to provide makeup water for P-Area. The 5G pumphouse provides cooling water to the D-Area powerhouse at about 3 cubic meters per second. The current combined cooling water flow requirement for these facilities is about 26 cubic meters per second. This withdrawal of river water could affect the fishes inhabiting areas on or adjacent to the Savannah River Plant in two ways:

- Entrainment of fish eggs and larvae through the cooling water system
- Impingement of larger fishes on the intake screens

Estimates of the impacts of entrainment and impingement are based on field data collected during past and present sampling programs performed in the SRP vicinity (Du Pont, 1985; Paller, O'Hara, and Osteen, 1985; Paller and Osteen, 1985). The following sections discuss the results of these investigations as summarized in DOE (1987). TE

Entrainment - The entrainment of fish eggs and larvae (ichthyoplankton) at intake structures is affected by a variety of factors including overall ichthyoplankton abundance in waters adjacent to the intake and percentage of river water withdrawn. The total magnitude and species composition of entrainment can also be influenced by aspects of intake design, the spatial distribution of ichthyoplankton relative to the intakes, and fish species behavioral and life history characteristics. The ultimate result of entrainment-related mortality on fish population persistence depends on the magnitude of species-specific mortality rates and the population level responses of the species to this added source of mortality.

Entrainment of ichthyoplankton into the SRP cooling water intake pumps removes them from the Savannah River population. Entrainment of ichthyoplankton is dependent on several factors including the density of organisms in the river, the amount of spawning in the intake canals, the volume of water withdrawn by each pump and, in the case of 1G intake, the density of organisms in Upper Three Runs Creek which enters the river immediately upstream of the 1G intake canal (Figure 2-1).

When fish larvae enter the intake canals from the river, they move from rapid currents to slow currents which may enable larger larvae to swim to protected shoreline areas. This behavior could reduce the mortality rate of larvae entrained from the river. However, there is evidence from the larval collections made during 1982 (ECS, 1983) that the intake canals are used as spawning sites by several species. Accordingly, loss of larvae for some species by entrainment may be greater than is indicated by the ichthyoplankton densities in the river water entering the canal. Consequently, larval entrainment at the 1G and 3G intakes was calculated using the larval density in the intake canals since these organisms are the ones most likely to be lost from the total Savannah River ichthyoplankton population, regardless of whether they were spawned in the canal or moved in on river currents. Larval densities in the Savannah River were used to calculate entrainment at the 5G intake because of the short length of this canal. BB-3 BB-5

The calculation of entrainment of fish eggs from the Savannah River into the three pumphouses was not as direct as the calculation of larval entrainment. Few eggs were actually collected in the canals. Generally, fish that spawn in freshwater have demersal rather than planktonic eggs. The only exceptions in the Savannah River drainage are the anadromous American shad and striped bass. The reduced current velocity in the intake canals allows the suspended eggs to settle out of the water column (McFarlane, 1982). Silt settles over these eggs and they die. The entrainment losses were calculated such that fish eggs that settle out of the water column and those actually entrained by the pumps are assumed to be lost. Consequently, the average egg densities used in the entrainment calculations were from the immediate upstream river transect. The egg densities for 3G and 5G are the same because they were calculated from the river transect immediately upstream of the 3G intake canal.

The density of eggs entering 1G canal was not calculated directly from the upstream river transect because a portion of the water entering 1G canal comes from Upper Three Runs Creek. The relative percent contribution of Upper Three Runs Creek and the river to the 1G intake canal water was estimated by measuring the sodium concentrations in the river upstream of the 1G canal, in Upper Three Runs Creek, and in the mixed water coming out of the pump. These percentages were multiplied by the density of eggs from each source to get an average density of fish eggs entering the 1G canal.

To estimate total entrainment of ichthyoplankton during a spawning season, the daily entrainment rates were multiplied by the number of days between samples, generally a week, and summed. Annual entrainment is considered to be equal to that which occurs during the February-July spawning season. There is generally very little ichthyoplankton in the river to be entrained from September to January.

A minimum of 17 species of larval fishes were entrained at the three intake structures at the SRP during 1983 (Table C-18). Because larval fish are difficult to identify, there were probably unidentified species in these collections. The most abundant family of fish collected was Clupeidae, the herring family, which comprised 59 percent of the total ichthyoplankton entrainment. The single most abundant taxon was the genus Dorosoma (gizzard shad and threadfin shad), with 10.5×10^6 larvae (37.4 percent). Other abundant taxa were crappie, blueback herring and minnows, which represented 14.1, 9.5 and 9.0 percent, respectively.

Total larval fish entrainment for the SRP from February-July 1983 was calculated to be 28.0×10^6, of which 12.9×10^6 larvae (46.2 percent) were from the 1G pumphouse, 13.2×10^6 larvae (47.3 percent) were from the 3G pumphouse and 1.8×10^6 (6.5 percent) were from the 5G pumphouse (Table C-19). BB-3 BD-5

At least 17 taxa of larval fish were entrained at the SRP pumphouses during the 1984 spawning season (Table C-20). As in 1983, the most common family found in the entrainment samples was Clupeidae, the herring and shad family, which comprised 50 percent of the larval fish that were entrained. The single most abundant taxon was crappie with 4.3×10^6 larvae (24.5 percent). Other abundant taxa were unidentified clupeids, blueback herring, and other shad (gizzard and/or threadfin shad), which comprised 23.9, 13.2 and 12.7 percent of the total larvae entrained, respectively. Generally, there were no differences in the species composition among the three pumphouses.

Total larval fish entrainment for the SRP from February to July 1984 was calculated to be 17.6×10^6. The 1G pumphouse entrained 7.7×10^6 larvae (44 percent), 8.8×10^6 larvae (50.3 percent) were entrained at the 3G pumphouse and 1.0×10^6 larvae (5.6 percent) at the 5G pumphouse (Table C-19).

At least 6 taxa of larvae were entrained at the SRP pumphouses in 1985 (Table C-21). The most common larval fish entrained were suckers, which comprised 43 percent of the larval fish entrained. The single most abundant taxon was spotted sucker with a total of 4.6×10^6 larvae (42.7 percent) entrained at the three pumphouses. Other abundant taxa were gizzard and/or

Table C-19. Estimated Entrainment of Larval Fish at SRP Intakes[a]

		1G	3G	5G	Total
1977[b]	Number ($x10^6$)	7.1	11.9	0.6	19.6
	Percent	36.2	60.7	3.1	
1982[c]	Number ($x10^6$)	5.2	12.0	0.7	17.9
	Percent	28.8	67.1	4.0	
1983[d]	Number ($x10^6$)	12.9	13.2	1.8	28.0
	Percent	46.2	47.3	6.5	
1984[e]	Number ($x10^6$)	7.7	8.8	1.0	17.6
	Percent	44.0	50.3	5.6	
1985[f]	Number ($x10^6$)	3.8	6.4	0.7	10.9
	Percent	34.9	58.7	6.4	
Average number ($x10^6$)		8.1	9.5	1.2	18.8
(1983-85) percent		43.4	50.3	6.3	

a. Source: DOE, 1987.
b. April-June, McFarlane et al. (1978).
c. March-August, ECS (1983).
d. February-July, Paller et al. (1984).
e. February-July, Paller et al. (1985).
f. February-July, Paller et al. (1986).

BB-3
BD-5

threadfin shad (22.0 percent), unidentified Clupeidae (11.4 percent), and carp (10.3 percent). Generally, there were no substantive differences in the species composition between the three pumphouses.

Total larval fish entrained due to SRP activities from February-July 1985 was calculated to be 10.9×10^6 (Table C-19). The 1G pumphouse entrained 3.8×10^6 larvae (35 percent); 6.4×10^6 larvae (59 percent) were entrained at the 3G pumphouse and 0.7×10^6 larvae (6 percent) at the 5G pumphouse.

For the five years for which data are available, estimated entrainment of larval fish was highest in 1983 when 28.0×10^6 larvae were entrained (Table C-19). Minimum larval entrainment (10.9×10^6 larvae) occurred in 1985. The 1983 estimated larval entrainment is almost 50 percent higher than the average entrainment (18.8×10^6 larvae) for the three year period (1983-85) during which sampling methodologies were consistent. The 1983-85 average entrainment is comparable to entrainment estimates for 1977 and 1982.

The highest percentage of larval entrainment occurred at the 3G intake during 1983-85 (9.5×10^6 larvae, 50.3 percent of total; Table C-19). Larval entrainment was substantially lower at the 1G intake (8.1×10^6 larvae, 43.4 percent of total). Larval entrainment at the 5G intake was consistently

Table C-20. Estimated Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses, February-July 1984[a]

Taxa	Pumphouse 1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	Percent Composition
Clupeidae					
American shad	36	26	-	62	0.4
Blueback herring	891	1398	39	2328	13.2
Other shad	1010	1085	139	2234	12.7
Unident. clupeids	2102	1975	116	4193	23.9
Esocidae					
Unident. pickerel	23	7	-	30	0.2
Cyprinidae					
Carp	175	203	46	424	2.4
Unident. cyprinids	449	679	167	1295	7.4
Catostomidae					
Spotted sucker	495	506	118	1119	6.4
Other suckers	-	23	12	35	0.2
Aphredoderidae					
Pirate perch	-	-	3	3	<0.1
Percichthyidae					
Striped bass	33	73	17	123	0.7
Centrarchidae					
Unident. crappie	1908	2181	233	4322	24.5
Unident. sunfish	147	100	22	269	1.5
Other centrarchids	200	59	16	275	1.6
Percidae					
Yellow perch	77	218	5	300	1.7
Other percids	84	219	39	342	1.9
Lepisosteidae					
Gar	19	-	-	19	0.1
Other	99	87	19	205	1.2
Total	7,748	8,839	991	17,578	100.0

a. Source: DOE, 1987.

BB-3
BD-5

Table C-21. Estimated Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses, February-July 1985[a]

Taxa	Pumphouse 1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	Percent Composition
Clupeidae					
American shad	46	9	5	60	0.6
Blueback herring	195	198	21	414	3.8
Other shad	563	1660	171	2394	22.0
Unident. clupeids	379	797	69	1245	11.4
Cyprinidae					
Carp	341	687	89	1117	10.3
Unident. cyprinids	122	225	61	408	3.8
Catostomidae					
Spotted sucker	1835	2585	223	4643	42.7
Unident. suckers	0	24	6	30	0.4
Others	341	195	39	575	5.1
Total	3,822	6,380	684	10,886	100.1

BB-3
BD-5

a. Source: DOE, 1987.

low (1.2×10^6 larvae, 6.3 percent), and never exceeded 6.5 percent of the total entrainment at the SRP river water intakes during 1983-85. Thus, the magnitude of larval entrainment at the SRP is primarily determined by losses at the 1G and 3G intakes.

The relative abundance of larval taxonomic groups entrained varies substantially from year-to-year. McFarlane et al. (1978) reported that clupeids (48 percent), primarily blueback herring (29.1 percent), were most abundant among entrained larvae in 1977. Cyprinid (10.0 percent) and catastomid (11.2 percent) larvae were relatively abundant. No striped bass eggs or larvae were collected during sampling in 1977.

Clupeid larvae also dominated entrainment collections during 1983-85. This group accounted for over 50 percent of larval entrainment in 1983 (Table C-18) and 1984 (Table C-20), but only approximately 38 percent in 1985 (Table C-21). Among the clupeids, gizzard and/or threadfin shad larvae were most abundant, representing 37.3, 12.7 and 22.0 percent of total larval entrainment in 1983, 1984, and 1985, respectively. Blueback herring represented 9.5, 13.2 and 3.8 percent of collections in those years. American shad larvae were a minor component of entrainment, ranging from 0.4 to 0.6 percent of entrainment from 1983-85.